London gekauft. 15/8/90

THIS TABLE IS COPYRIGHT.

Sensitometer Number of Plate Employed. / Last No. Visible	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12
28	1	$1\frac{1}{3}$	$1\frac{3}{4}$	$2\frac{1}{3}$	3	4	5	7	9	12	16	21	28	37	50	67	90	120	180
27	$1\frac{1}{3}$	$1\frac{3}{4}$	$2\frac{1}{3}$	3	4	5	7	9	12	16	21	28	37	50	67	90	120	180	240
26	$1\frac{3}{4}$	$2\frac{1}{3}$	3	4	5	7	9	12	16	21	28	37	50	67	90	120	180	240	320
25	$2\frac{1}{3}$	3	4	5	7	9	12	16	21	28	37	50	67	90	120	180	240	320	426
24	3	4	5	7	9	12	16	21	28	37	50	67	90	120	180	240	320	426	568
23	4	5	7	9	12	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$
22	5	7	9	12	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′
21	7	9	12	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′
20	9	12	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′
19	12	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′
18	16	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′
17	21	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′
16	28	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′	100′
15	37	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′	100′	135′
14	50	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′	100′	135′	180′
13	67	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′	100′	135′	180′	240′
12	90	120	180	240	320	426	568	$12\frac{1}{2}'$	17′	23′	30′	42′	55′	75′	100′	135′	180′	240′	320′

Exposures Required (in Seconds up to Ten Minutes).

TABLE OF EXPOSURES.

See p. 40.

20·4

A GUIDE

TO

THE SCIENCE OF

PHOTO-MICROGRAPHY;

CONTAINING

EXPOSURE-TABLES AND RULES FOR WORKING.

BY

EDWARD C. BOUSFIELD,

L.R.C.P., LOND.

London Agents:

W. KENT & CO., 23, PATERNOSTER ROW, E.C.,

AND

H. H. SHARLAND, 7 & 8, THAVIE'S INN, E.C.

And to be had of all Booksellers, Opticians, and Photographers.

1887.

PREFACE.

This attempt to smooth the road to success in the fascinating branch of Microscopic science with which it deals, was begun some two years ago, but pressure of professional work, and the constant developments of Photographic and Microscopic science, needing fresh experiments to ascertain their value in Photo-micrography, have hitherto prevented its appearance.

I only claim to have recommended nothing that I have not found successful in daily working, and with this, and my thanks to Frank Crisp, Esq., Secretary of the Royal Microscopical Society, for his kindness in looking over the microscopic portions of the work, I send it forth to take the place to which its merits may entitle it, whatever that place may be.

EDWARD C. BOUSFIELD.

363, OLD KENT ROAD, S.E.,
April 15, 1887.

INDEX.

A GUIDE

TO THE

SCIENCE OF PHOTO-MICROGRAPHY.

CHAPTER I.

INTRODUCTORY REMARKS.

THE history of Photo-micrography is practically co-extensive with that of camera photography. But little time had elapsed after the first experiments in the reproduction of images by means of light, before attempts were made to reproduce those given by the microscope, and the experiments of Wedgwood and Davy, in 1802, marked the commencement of a new era in microscopic work. These experimenters did not succeed in fixing the pictures which they obtained, but a start was made, and from that day to this the progress of photography in connection with microscopic work has been steady and continuous, and of late years very rapid. Each new process, as brought forward, has been pressed into the service, and with the introduction of the dry-plate, or emulsion process, by Dr. Maddox (perhaps the first

Photo-micrographer of the day), the number of microscopists who have endeavoured thus to perpetuate the objects brought before them has increased very rapidly. The collodion process no doubt gives results which for certain purposes remain so far unsurpassed, from the absence of grain, and therefore possible delicacy of detail, in the negatives yielded by it, but the processes involved are so much more complicated, and, it may be added, so much dirtier, than in dry-plate working, that for the purposes of the microscopic worker who desires to add photography to the resources at his command, there is no comparison between the two.

The uses of Photo-micrography are so manifold, that it is not surprising that the introduction of a method so easy as the dry-plate process should have been followed by a rapid increase in the number of practitioners of the art. Few indeed are the microscopists who have not, at some time or other, longed to be able to obtain easily and rapidly reproductions of the various objects which have particularly attracted their attention. Every worker who pursues microscopy as a study (as well as an amusement), must from time to time meet with objects new, or rare, or imperfectly known, of which an accurate representation might be of great benefit to science, and also the means of adding to his reputation as a scientific worker, and so enlarging his circle; in itself a great advantage to every student of science.

Such artistic skill as that which has made the name of Mr. Tuffen West so deservedly famous in this connection, falls to the lot of only one here and there, and few are the microscopists, comparatively at least, who possess the power of easily and rapidly delineating an object of interest, whilst, if the object be of a complicated character, even the most skilled artist will require a considerable time for its representation.

The art of Photo-micrography, however, offers a means of reproducing, with the greatest fidelity, objects of the most complex nature, and in point of time there is no comparison between this method and the former; in fact, very many, and some of the most difficult, objects can, after a moderate amount of practice, be photographed in the time which an artist would take to sharpen his pencil, or rub his colour. Moreover, even the most successful drawing is but one, whilst a Photo-micrographic negative may be made the means of producing hundreds of copies, all exactly alike.

The Photo-micrographer has the additional advantage of being independent of external considerations. Hail, rain, snow, or blow, he can set up his apparatus and go to work in spite of the weather, whilst the recent improvements in printing processes enable him to complete the stages down to the finished print, without the aid of any greater light than that to be obtained from a good paraffin lamp.

Micro-photography or Photo-micrography? Much discussion has taken place over the question of the name to be applied to the art, and this question is not yet settled. The present writer prefers the older, and, as he ventures to think, the more correct term, inasmuch as the art consists in adapting photographic methods to the microscope, and not micrographic ones to the photoscope. In deference to the present state of opinion upon the point, however, he adopts the newer form of title in the present work; but he thinks that Macro-photography would probably more nearly express the true scope of the art than any other, since the pictures produced by it are enlargements, obtained by photography from small objects.

Photo-micrography has not hitherto risen far above the position of an art—that is to say, it has

been more a question of practice than of rules, and the conditions upon which success depends have been arrived at only as the result of experiment, eliminating possible causes of failure, and so by slow and gradual means something like perfection has been reached by a few skilled workers, many of whom have failed, from selfishness or negligence, to do more than make known the results they have obtained, their methods of working being still concealed. To this fact may be chiefly attributed the comparatively restricted application of Photo-micrography; but signs are not wanting that a more liberal and scientific spirit is prevailing, and with an increase in general information on the subject may be expected more rapid advances, and a more accurate knowledge of the rules on which success depends.

The first attempt to lay down anything like a fixed rule in Photo-micrography is to be found in a little work by Dr. Viallanes,* where he states that the time required for exposure is that which would suffice to print 13 of Warnerke's standard sensitometer upon the plate used, with the same light. No further indication is, however, given; but starting from this point the present writer set himself to determine experimentally what the time in question actually was, with a given plate and a given light, and the result is embodied in a table, which is, he believes, the first attempt to furnish absolute data for exposure, in his opinion the most difficult of all the questions which arise for the consideration of the Photo-micrographer. Following on these lines, he has to some extent fixed the alterations required in dealing with coloured objects, and ventures to hope that he has thereby done something to raise

* La photographie appliquée aux études d'anatomie microscopique.

this attractive work to a higher level, and so smooth the difficulties in the way of the beginner. Success in this, as in any other pursuit of the same kind, is the result of careful analysis of failures, and scrupulous attention to details, but given these, that success is certain, and every failure, if properly utilised, makes it more so. The rules to be given hereafter will, the writer believes, be sufficient to save even the tyro from *gross* failures; but he does not pretend for a moment that he has covered the whole ground, nor that the last word as to exact data has now been said. On the contrary, he himself continues his experiments, in the hope of learning still more accurately the essentials upon which success depends, and the more numerous his fellow-workers, the more rapidly and certainly will that success arrive. To this end the beginner is recommended to make a careful record of every plate exposed, in a tabular form, giving the object, the objective and eyepiece, the intensity of the light and its source, the length of exposure, the developer employed and the results, with a reference number by which the plate can be afterwards identified. If this be conscientiously done, a mass of information will be accumulated, which, acted on in subsequent trials, will do much to place within the grasp of the worker the principles of the SCIENCE of Photomicrography.

CHAPTER II.

PHOTOGRAPHIC ACCESSORIES REQUIRED.

THE would-be Photo-micrographer is strongly recommended to make all his arrangements for dealing with the dry-plates before he attempts to expose one in the camera, and the first place is therefore given to the department which heads the present chapter. One word may be said by way of caution. The writer has no intention of entering farther upon the discussion of photographic processes, pure and simple, than will enable the beginner to deal with the difficulties he is likely to meet with. This little work is not meant to be a treatise on photography, and the writer ventures, therefore, to adopt a more dogmatic tone than would then be right or proper. He wishes to place the details of processes, which he has himself found satisfactory, before his readers. Those who wish to know more of photography, as distinct from Photo-micrography, cannot do better than begin with the "Instructions for Beginners" of Mr. Wyles, a thoroughly practical and reliable little book, and having mastered that, pass on to Captain Abney's "Photography with Emulsions." With these works they will be in a position to know the greater portion of what is worth knowing upon the subject.

DARK ROOM.—The first requisite to the production of satisfactory photographs is a room from which all light capable of acting upon the plates employed

can be entirely excluded. Supposing the room to have a window, this should be covered with at least two thicknesses of "orange demy" paper, and if the external light be strong, an additional thickness will be needed. But, as the safety of the light depends upon the colour, and not upon the quantity, the paper may be made more transparent by coating it with boiled linseed oil or varnish. If the window be a small one, the "Glacier" material used for decorative purposes may be conveniently employed; one thickness of yellow and one of ruby will give all needful safety, except for orthochromatic plates, when an additional thickness of ruby may be added instead of the orange. For artificial light, the writer prefers to everything else a small paraffin lamp, enclosed in a screen of galvanized netting, on one side of which are two, and on the other four, thicknesses of orange tissue paper, treated as previously described. With this lantern, by simply turning round the screen, the weaker light is available for changing plates, and for the early stages of development, whilst the stronger can be used for purposes such as watching the progress of development, where more light is needed.

The light having been satisfactorily arranged, and a supply of water, with a means of getting rid of that which has been used, provided, not forgetting a table at which to work, which should be of sufficient size to allow the operator some freedom of movement, the next thing is to provide dishes. These are best if made of glass or ebonite; the writer prefers to use glass for pyrogallic acid development, and ebonite for ferrous oxalate. There is then no risk of ruining negatives by contamination of one re-agent with another. For the fixing and clearing solutions the writer uses porcelain dishes; thus the materials of the dishes indicate sufficiently their contents and purposes. The more dishes the

better, and two of each size likely to be wanted should be at hand. They are not expensive, and the want of a sufficient supply soon becomes a nuisance. For washing purposes a large porcelain dish, 12 by 10 inches, is very convenient. Add to the foregoing two glass measures, each of four ounces capacity, and the apparatus likely to be required is complete.

For chemicals, the following will be found requisite :

Pyrogallic Acid.	Oxalate of Potash.
Sulphite of Soda.	Sulphate of Iron.
Carbonate of Soda (not Bicarbonate).	Alum.
	Citric Acid.
Hyposulphite of Soda.	Corrosive Sublimate.
Bromide of Potassium.	Strong Solution of Ammonia (880°).
Red Prussiate of Potash.	
Chloride of Gold.	Acetate of Soda.

The above will be likely to satisfy all the requirements of the beginner ; and he is likely, too, to require them all before he has been long at work.

Developers.—Much has been written on the subject of development, and every maker of dry-plate has a formula which he sends out with his plates, whilst it is not rare to find added a caution that no other should be used. The writer may as well say at once that he pays no attention whatever to these instructions, and that having found one developer which answers all his requirements, whatever the make of plates in use, he employs it constantly. The formula is modified from the extravagant one given by the Eastman-Walker Co. with their Negative Tissue, and is as follows (the weights being avoirdupois) :

A. Pyrogallic Acid, $\frac{1}{4}$ ounce.
Pure Sulphite of Soda, $1\frac{1}{2}$ ounce.
Distilled or Boiled Water to make 10 ounces.

B. Pure Carbonate of Soda, 1 ounce. 10%
Water, as before, to make 10 ounces.

C. Potassium Bromide, $\frac{1}{4}$ ounce. 5%
Water, to make 5 ounces.

For a standard developer, take one drachm each of A and B, ten drops of C, and one ounce of water. This is sufficient for a quarter-plate negative in a dish of suitable size. Increased density may be obtained by diminishing the proportion of water. It is not advisable to make up more of the stock solution A than is likely to be used in a fortnight. Even the purest sulphite of soda has a tendency to become oxidized to sulphate. The action of the developer is thus greatly retarded, and whilst this may be overcome by adding fresh pyrogallic acid, the negatives will probably be deeply stained.

When a negative is known to have received correct exposure, the ferrous oxalate developer may be advantageously employed. It is made as follows:

1. Saturated Solution of Neutral Oxalate of Potash, 9 drachms.

2. Saturated Solution of Sulphate of Iron, 3 drachms (in two portions).

The iron solution is to be measured first, and the potash solution added. The latter must not be in the least alkaline, and to guard against this, it should be rendered feebly acid to litmus paper, by the addition of a small quantity of citric acid. The foregoing solutions, viz., A, B, C, and 1, 2, may be made before they are required; but the developing solution for use must not be mixed until wanted, as, in either case, oxidation goes on rapidly, and the solution would shortly fail to act.

The fixing solution is composed of:

Hyposulphite of Soda, 1 ounce.
Water, 10 ounces.

The clearing solution is made by dissolving two ounces of citric acid in a pint of *saturated* solution of common alum.

CHOICE OF PLATES.—The worker is strongly advised to purchase only those plates which have the sensitometer number marked upon the box which contains them. When it is remembered that a difference of two numbers on the sensitometer implies that one plate is half, or twice, as sensitive as another, it will be at once seen that under or over exposure may, and most likely will, occur with plates whose sensibility is no more accurately expressed than in the descriptions, "ordinary," "rapid," "extra rapid," "instantaneous," or as the fancy of the maker may dictate. Some makers style their plates "XL" or "XXXXX," implying that they are that number of times more rapid than wet collodion ; but as the latter criterion is in itself as uncertain as it well can be, the purchaser is no nearer the mark than when the sensitiveness is described by one of the terms given above. As some of the most rapid and most reliable plates in the market are tested by the makers, and bear the sensitometer number upon them, the worker, at all events at first, will find it unnecessary to place himself in any difficulty on this point. Of such plates as the last-mentioned, Cadett's among the more expensive, and Ilford among the cheaper, have yielded good results in the writer's hands. In order that the table of exposures given hereafter may prove useful the worker must know the sensitometer number of his plates within a point at least, and whilst he may determine this by means of the table itself, there is in the writer's opinion no reason whatever why he should sacrifice a plate from each box or batch for that purpose when the maker should do it for him. Those makers who do take this trouble should certainly be encouraged,

and the writer therefore refrains from publishing in this place the results of experiments which he has made to determine (so as to make them available) the sensibility of the plates of those makers who do not mark their issues which have come into his hands.

NEGATIVE PAPERS.—The use of lighter and less fragile material than glass as a backing for the sensitive film is of comparatively recent date, but considerable progress has already been made in its manufacture, and it offers many advantages. The negative tissues of Warnerke, Eastman, and Morgan and Kidd, are all about equally sensitive, giving about 15 upon the sensitometer scale, but of course requiring a very much longer exposure than is needed for such plates as give 25. The results in other respects, however, can hardly be surpassed, and as they can be cut to any size required, their use is more economical than that of even cheap glass plates. The writer purchases them in continuous spools, to avoid waste, and recommends them for trial. As time goes on, the sensibility of these tissues will probably be greatly increased, and they will become formidable rivals of glass plates. The paper cannot, of course, be exposed in the dark slide in the same way as a glass plate, by merely allowing it to rest on the corners, and the writer usually places it between two plates of glass, the small difference in the position of the sensitive film thus occasioned having no effect under Photomicrographic conditions. Another, and perhaps a better, method is to use pieces of sheet metal (thin hard sheet brass, for instance). In each piece is cut a hole rather smaller than the size of the paper intended to be used with it, so that the paper may overlap slightly all round. Behind this again is placed a glass plate, and the exposure can then be made in the usual way.

CHAPTER III.

THE MICROSCOPE AND CAMERA.

PRESUMING that the reader is a microscopist, rather than a photographer, and that is probably the position of most of those into whose hands this book will come, the side of the question to be considered is rather, how to apply the stand which he already possesses to Photo-micrographic work, than, what is the most suitable stand for the purpose, and that side of the question will therefore be chiefly dwelt upon in this chapter. A microscopist—that is to say, a microscopic *worker*—has been compelled to learn how to bring out the points of the objects he meets with, and how to get "full duty" from his objectives and illuminating apparatus, though perhaps there are comparatively few who can do the utmost that their lenses are capable of. A photographer, however, who wishes to apply his art to microscopy, finds himself in a very different position. Not only has he to choose his apparatus, but to learn how to use it, and such knowledge is the result of experience—in some branches, of long experience. He has, moreover, this being done, to modify the processes which have proved adequate to his previous requirements, and to bring them into harmony with a new "environment." His task is consequently a much longer one than that of the microscopist who starts photography, as the latter,

without previous prejudice, has simply to adopt those methods, neither numerous nor difficult of application, which have been successful in the hands of others.

To photographers who wish to take up Photo-micrography, the stand which the writer would recommend is Swift's latest Jackson-Lister model. But there are many others little behind this one; the writer has found a stand by Baker, also on the Jackson-Lister model, but somewhat modified, with Campbell's fine adjustment, in every way excellent. Of all things, the fine adjustment must be looked to, as upon its absolute reliability success will in many cases depend, and any stand, however attractive and convenient to outward appearance, which is wanting in this essential point, will prove to be dear in the end.

Several makers of apparatus supply Photo-micrographic sets complete, with a microscope specially adapted, but such sets are rather luxuries for the wealthy amateur than for the worker of ordinary means. Messrs. Baker, however, are now bringing out a good and cheap form of camera, at the low price of £2 10s., which can be easily adapted to any microscope, and from what the writer has seen of it, he is disposed to regard it very favourably. There is a special frictional apparatus for rendering the slow motion readily available, and the whole apparatus is worked out with an evident knowledge of the needs of the Photo-micrographer.

Supposing the stand to be decided upon, with special reference to the fine adjustment, and to general steadiness and smoothness of working, or supposing that the microscopist wishes to use his own stand, to which he is accustomed, how is it to be done? The writer thinks it best to describe the form of apparatus which he himself uses, as being simple and inexpensive, whilst for general efficiency

it is all that is required. It consists of three parts: the base-board, the carrier, and the camera.

The base-board is of stout deal, seven feet long, hinged at three feet from one end. This allows of the board being folded when a short camera is needed, and is a great convenience. The board is nine inches wide, one inch thick, and has cross pieces on the under side to prevent warping. It is planed as true as possible, that the carrier may run easily upon it, the edges especially being carefully made straight and smooth.

Upon this base-board slides the carrier, which is of mahogany, 15 inches long, and of the same width as the base-board. Vertical pieces, of the same length as the carrier, and sufficiently deep to overlap the edges of the base-board, and act as guides, are attached on either side of the carrier, which, to lessen friction, runs upon four slips of wood, of a suitable height, fixed on the under surface. A slot is cut in its centre nearly the whole length, so as to allow of a certain amount of movement of the camera in the direction of increased length, without the use of the tail of the base-board.

The camera itself is of the old-fashioned sliding box-body pattern, half plate size ($6\frac{1}{2}$ by $4\frac{3}{4}$), and has a lens-aperture of nearly 4 inches diameter. Through the bottom, as far forward as possible, a hole is made to receive a thumb-bolt, the socket of which is on the under side of the slot in the carrier. For ordinary work, when eye-pieces are used, the lenses of the camera are unscrewed, and their tube is used to form the connection between the microscope and the camera, whilst for greater lengths the tube is removed, and a bellows substituted.

The dark slide and ground-glass screen in no way differ from the ordinary form; but a second screen, of patent plate-glass, ruled on the front with very fine lines (not scratches), fits the frame of the ground-

glass screen, and is used, in conjunction with a Zeiss' aplanatic magnifier, when delicate detail has to be brought out and focussed.

The foregoing apparatus is very inexpensive; in fact, the total cost did not exceed thirty shillings, including the base-board; but, with a little ingenuity, a square wooden box, such as may be purchased for a few pence at any grocer's, may be made to do as good work as the most expensive forms. The dark slide should be purchased in any case, but the remainder of the apparatus can easily be made at home. Metal dark slides, holding two plates, may now be obtained at a very reasonable rate, and their freedom from warping recommends them strongly, especially for use in hot or damp climates. It is desirable that the whole front of the camera should be so constructed as to slide in grooves, in order that, when an unrestricted field is required, with considerable length of camera, a bellows, whose frame fits the same grooves, may be substituted for it, or the front itself may, if preferred, be made to fit the front frame of the bellows. Either arrangement simply amounts to the interposition of a bellows between the front and the body of the camera. The bellows may be made of paper or cloth, and directions for so doing will be found in the *Year Book of Photography* for 1886, by following which the cost is reduced to a minimum.

It need scarcely be added that whatever arrangement be chosen, it must be perfectly light-tight, or good results cannot be expected. It is also advisable that the size should not be smaller than that above mentioned. The worker will be wise in confining himself to quarter-plates at first, until he has had sufficient practice to give some certainty to the result of the exposure, as the expense of plates is by far the largest in the cost of working, and a quarter-

plate is quite large enough to spoil. To allow of the use of different sizes, the dark slide should be furnished with frames, fitting one within the other, capable of receiving plates of such sizes as $6\frac{1}{2}$ by $4\frac{3}{4}$, 5 by 4, 4 by 4, $4\frac{1}{4}$ by $3\frac{1}{4}$, and $3\frac{1}{4}$ by $3\frac{1}{4}$. The first, second, and fourth of these are required for the regulation plates of corresponding sizes, whilst the third is useful for the exposure of negative paper, and the last for that and for "lantern-size" plates. Any of the foregoing which are not supplied with the dark slide, can easily be constructed either of thin wood or stout millboard.

In adapting the ordinary photographic camera to Photo-micrographic purposes, the size of the aperture for the lens requires attention. If this be small, the field will be much restricted, unless the camera be capable of considerable extension, and the full field of the microscope will only be available at short distances. The expense of having the front of the camera made removable will not be great, and the work is within the capacity of any fairly skilful cabinet-maker, whilst the advantage is very great, and at times, even the largest lens aperture is too small, especially when the camera is extended to any considerable length.

On the whole the writer is inclined to favour that form of Photo-micrographic camera in which the body is represented simply by a frame (into which the dark slide fits) of suitable height, sliding upon the base-board, bellows being attached to the frame, and to a support close to the microscope. Such an arrangement leaves little to be desired in point of simplicity and completeness.

CHAPTER IV.

OPTICAL APPARATUS.

THE form of stand to be selected for Photo-micrography having been referred to in the previous chapter, it remains to consider the optical appliances, objectives, and so forth to be employed.

The question whether or no the eyepiece should be used has been much debated, some authorities contending against its use, and others, of equal weight, in favour of it.

Two chief objections have been urged ; the first, that the field of view is restricted by it ; the second, and more important, the loss of light. In the opinion of the writer, the truth lies between the two opinions just now mentioned, and the matter must be decided according to the nature of the object and the objective which is selected as being the most suitable to bring out its details. The lowest objective which will accomplish this should be the one chosen, and this being so, the sole criterion, in an ordinary case, will be the magnification to be produced upon the screen, or in other words, the size of the picture which is to be taken. Where the loss of light is of no importance, and a somewhat increased exposure is not a vital point in view of the results wished for, the shortness of camera, and consequent facility of working, allowed by the use of the eyepiece, constitutes a very great advantage, and the additional

length of exposure is saved, as time in focussing, by the convenience of being able to watch the image upon the screen during the process, so ensuring correspondence between hand and eye, without special and expensive arrangements, such as are necessitated by the use of a long camera if it is to be worked with a reasonable degree of comfort to the operator.

Where rapidity is the main point to be obtained, the use of the eyepiece must be dispensed with. Even then, however, the use of an amplifier may perhaps be admissible, and the gain, as compared with the eyepiece, is considerable. The ordinary amplifier, however, is not very satisfactory for this purpose, since it absorbs nearly as much light as the *A* eyepiece, if by the *A* be understood one of about 2-inch focus.

The writer's experiments, using the same (*a*) illumination, (*b*) objective, (*c*) magnification, gave the following results :

Without eyepiece	1
With amplifier	$1\frac{1}{3}$
With *B* eyepiece	$1\frac{2}{3}$

In this table the unit is the time required to print a given number of the sensitometer on a given plate, the results will vary according to the particular make of eyepiece, but they are approximately correct.

It should be added that, inasmuch as all objectives are constructed for use with eyepieces, it is not surprising that some should not give their best results when used without them, and this the writer has found to be the case.

Until recently it has been necessary for the Photo-micrographer, either to provide himself with objectives specially corrected for Photo-micrography, or to have those already in his possession so corrected (which was done by placing a biconvex

lens of suitable curvature behind the back combination), or having determined experimentally the difference between the visual and actinic foci, to apply the correction thus found to be necessary in the case of any objective, on every occasion when that objective was used. To obviate this annoyance some operators advocated the use of mono-chromatic light ; but this could be but partially successful, and only so at all in dealing with colourless objects.

Of late years, however, such great strides have been made in the manufacture of objectives that the worker whose lenses are of recent production, by good makers, will probably find that no correction is required. None of the writer's objectives were specially purchased for use in Photo-micrography ; but they are all available without special provision—that is to say, the corrections are such that the visual and actinic foci are practically coincident. Considering that they include a $\frac{2}{3}$-inch of variable power, by Baker, an *a* 24 and an *A*, by Zeiss, a $\frac{1}{2}$-inch, by some maker unknown, and a water immersion $\frac{1}{10}$th, by Beck, this cannot but be considered an evidence of the improvements which have been made in the construction of lenses of moderate price. As some readers, however, may find that their objectives are not so corrected as to give good results, the method of testing them will be given hereafter, in the chapter dealing with the photographing of special objects. Those who are purchasing objectives especially for Photo-micrographic work will do well to examine the lenses of those opticians—notably Swift and Crouch—who make a speciality of objectives for that purpose. The performances of these lenses in ordinary working is said to be in no way deteriorated by the special correction for photographic work, and the writer recommends them for trial.

In addition to the use of eyepiece and objective, some form of substage condenser, in addition to the bull's-eye, is an absolutely indispensable piece of apparatus for Photo-micrography. For such work as photographing bacteria, or the more difficult diatoms, where the objectives employed will necessarily be those of large aperture, the condenser must be of proportionate power, or no good results need be expected. To use an objective of 1.4 N.A. with a condenser of 1 N.A. simply amounts to reducing the aperture of the objective to that extent, as may be seen by taking out the eyepiece and looking down the tube at the back lens of the objective, when the part utilized will be seen as a bright spot, whilst the width of the greyish-black ring round it will show how much of the aperture is left unused ; in the case supposed, this will amount to nearly one-third. Against this, however, must be set the fact that the objectives which will stand filling with light are very few. For instance, the writer's half-inch, when tested recently by Mr. E. M. Nelson, perhaps the highest authority on such matters, showed no sign of falling off in definition when up to 6-7ths of its full aperture (70°=N.A.,·58) was used, but the extension of the angle of the cone of rays from the condenser to 70°, gave rise at once to a woolly appearance which had been absent before. Even such a result as this, however, is far better than could have been expected, considering the cost of the objective, £2 10s. In addition to this, there is the fact, difficult of explanation, but true nevertheless, that a less degree of aperture in the condenser will give good results upon the screen or plate, than will suffice for observation directly through the microscope.

Mr. Nelson suggested to the writer the employment of a lens of hemispherical form, four-tenths of an inch in diameter, as a substage condenser ; and

such a lens having been mounted for him by Messrs. Baker in a manner which allows of the use of either direct or dark-ground illumination, at a cost of ten shillings he obtained a condenser which practically doubled the power of his objectives so far as resolution goes. The lens is mounted by Messrs. Baker in a setting which slips into a screw-collar, so that central or other stops can be interposed between the two, and the screw-collar being of the standard or "Society" pitch, an alternative plan, consisting of employing as a condenser the next lower objective than the one employed for viewing the object, can be readily carried out. For dark-ground illumination, the results obtained by using the simple lens above described with a central stop of suitable size, are infinitely superior to those obtained by the paraboloid, or by oblique illumination, up to powers of $\frac{2}{3}$-inch focus.

The foregoing paragraph refers chiefly, so far as its wording goes, to direct microscopic observation; but every word is equally true for Photo-micrographic work. For those to whom expense is no object, the oil-immersion condenser of Powell and Lealand, price £12 12s., is far beyond everything else; but from this there are various forms, including especially the condenser of Abbe, at £1 15s. for N.A. 1.2, and £2 for N.A. 1.4, and so on, down to the simple lens above described, and the choice must be left to the worker himself, to be made according to his means and requirements.

The Abbe condenser, as adapted by Messrs. Baker to stands of the English model, deserves special mention. The form of N.A. 1.4 is that now employed by the writer. For low powers, by removing the front hemisphere of the condenser, a large circle of light is available, with, of course, a corresponding diminution of aperture; whilst, with the hemisphere in place, the writer found no

difficulty in photographing *Amphipleura pellucida*, than which there are few, if any, severer tests. Another advantage is that, either with or without the front hemisphere, magnificent dark-ground illumination can be obtained by the use of central stops of suitable size.

A few words about the "bull's-eye" will fitly conclude this chapter. Properly used, it is one of the most important adjuncts of the Photo-micrographer, and, in fact, of the general Microscopist. For Photo-micrographic work, however, when low powers are used in combination with the substage condenser, the small bull's-eye, of two inches or even less diameter, is not of much use, inasmuch as the method of illumination to be described in the next chapter involves working with the image of the bull's-eye as the ground on which the objects are displayed. It is advisable, therefore, to be provided with a considerably larger one, and the focus should be short, since upon that factor depends the intensity of the light obtained from the "bull's-eye." The best form is that which is made up of two lenses, a double-convex and a meniscus; its collecting power is greater, and it is achromatic, which, of course, is not the case with the ordinary form.

CHAPTER V.

ILLUMINATION.—SETTING UP THE APPARATUS.

PRESUMING the reader to have procured the necessary additional apparatus, we now proceed to indicate the best method of bringing it into use for photo-micrographic purposes.

As to the source of light, there can be no doubt that for safety, convenience, and cheapness, there is nothing at all equal to a really good paraffin lamp, with a flat flame burner. The light from magnesium, incandescent carbon, the oxy-calcium lamp, the electric arc, and direct sunlight, are no doubt more intense, in the order in which they are named successively; but for the ordinary worker the special appliances required and the expense thereby incurred, put all but magnesium quite out of court. Even magnesium has its disadvantages. For short exposures, up to five seconds, it is fairly easy to deal with it; but beyond this there is great practical difficulty in keeping the point of light in the optical axis of the microscope, whilst still allowing the wire or ribbon to burn freely. The writer has tried to overcome this by burning the wire in the point of a spirit-lamp flame (made luminous for focussing purposes by means of salt), but the carbonic acid from the flame of the lamp greatly mars the brilliancy of

the magnesium light, and the only course appears to be to burn it a little way behind the flame, taking care, as will be seen immediately, that its burning extremity remains in the focus of the bull's-eye. Even then, however, there is great difficulty in so arranging the rate of passage that the wire shall have its extremity constantly at the same point. The best way seems to be to allow the magnesium to pass through a slit, and so to arrange the rate of movement that about half an inch is always beyond the slit.

[NOTE.—Since writing the foregoing passage the writer has had the opportunity of experimenting with the oxy-hydrogen light in a form at once cheap and manageable. The oxygen is supplied in cylinders holding 10 feet (or more), of a convenient size, and the burner, instead of being a cylinder of lime, of considerable size, and great sensitiveness to damp, is a small disc of refractory material, which can be made intensely hot in the oxy-hydrogen flame from a common Herapath blow-pipe, can be arranged in the focus of the bull's-eye (see below), and gives results with which even the best form of lamp cannot for a moment compare, either for direct observation or upon the ground-glass screen. The ideal conditions of illumination are, in fact, realised as nearly as possible, and when the light becomes more generally known the writer believes that it is destined to take the front rank among the various methods of illumination at the disposal of the Photo-micrographer. The price of the oxygen is sixpence per foot, and the lentilles, or burners, cost sixpence each, and are capable of being used for a long time. Both may be obtained of Brin's Oxygen Company, Connaught Mansions, Victoria Street, Westminster.]

Of paraffin lamps the writer has used several, and prefers to all others the burner known as the

"Paragon," manufactured by Messrs. Dietz & Co. That which he regularly uses has a flat wick, one and a half inches wide ; the lamp itself, to the top of the slit, stands six inches high, and the reservoir holds a pint of oil, giving an intense light for about fifteen hours with once filling, whilst a screw-cap on the side of the reservoir allows of the lamp being refilled without removing the top, a great advantage during prolonged exposures. Used in the way to be immediately described, the light to be obtained from this lamp is, with a half-inch, absolutely painful ; but it can, of course, be moderated to any extent that may be convenient by turning down the wick, or by interposing coloured screens. It may be added that the only fault of the "Paragon" lamp is that the chimneys frequently break ; but since the writer adopted the plan of baking them for 24 hours in the oven before use, he has had no trouble from this cause.

The table of exposures given hereafter was constructed with this lamp, and inasmuch as the cost is not great, the reader who wishes to make use of the table will do well to procure a lamp similar to that described (which may be obtained of Messrs. R. & J. Slack, Strand), that he may be sure of employing a light of the same actinic intensity as that upon which the calculations were based, though it is not intended to be implied that this is absolutely necessary, since even with the oxy-hydrogen light, the table still gives correct indications.

The lamp being properly trimmed, so that the edges of the flame are parallel, or only slightly convex, the question to be considered is, how is it to be used to the best advantage ? And here the writer desires to express his indebtedness to Mr. E. M. Nelson, from whom he has learnt practically all that he knows on the subject that is worth knowing, the information having been

communicated partly orally, and partly in the writings of Mr. Nelson, an excellent summary of which, containing a most masterly, though by no means lengthy, treatise on the use of the bull's-eye, the *crux* of the whole subject, will be found in the journal of the Royal Microscopical Society for August, 1885. The microscopist who is not acquainted with the principles and methods therein laid down cannot be said to have mastered the art of illumination.

The question of procuring illumination, and of adjusting the camera, being closely connected, the two will be considered together. The mode of arrangement is as follows: A circular diatom (*Aulacodiscus margaritaceus*, for choice) having been placed upon the stage of the microscope, and focussed with the 1-inch objective, in the centre of the field, is secured in position in the usual way, by springs or otherwise. The microscope is then inclined horizontally, and placed upon the base-board, or other support, at a foot from one end, and as centrally as possible, the under part of the stage being nearest the end.

Opposite this the lamp is now placed, the *long axis* of the flame being in the optical axis of the microscope, so that the edge of the flame is presented to the object. The substage condenser is then put in, and moved up until the image of the flame which it forms is across the diatom, and both are in focus together, as sharply as possible. The objective and condenser are now at their best points in relation to each other, and the object is in the conjugate foci of the two. For critical observation nothing could be better, and if the objective shows no sign of fog or woolliness under the illumination thus yielded by a condenser of equal aperture, it may safely be pronounced a first-rate lens. For photographic work, however, it is usually desirable to have the field

evenly illuminated, and this may be accomplished by withdrawing the substage condenser to a point sufficiently below its proper focus; but the result is great loss, not only of light, but, and this is of much greater consequence, of aperture, and consequent defining power in the objective. This the worker may readily test. Restoring the focus of the condenser, let him remove the eyepiece, and look at the back lens of the objective. With the proper aperture of the condenser, it will appear as a bright circle of light, up to the edge. Let him now withdraw the condenser again until the field is fully covered by the image of the flame spread out, and on again looking at the back lens of the objective, he will find that he has in view a small circle of light surrounded by a halo of a black or greyish colour. The small circle of light shows the portion of the back lens, that is of the aperture, which is utilised, and for all practical purposes the objective may be considered to be "stopped down" to that aperture.

Once more restoring the condenser to its position, in focus, let the worker try the effect of the bull's-eye, used as recommended by Mr. Nelson, and he will be surprised at the effect. The bull's-eye is to be interposed between the lamp and the substage condenser, in such a position that the edge of the lamp-flame occupies its focus. This is the case when the image of the bull's-eye, viewed through the microscope, appears on the field as a circle of light, with a narrow dark margin, broken at the top and bottom by a luminous cone prolonged from the circle. When the bull's-eye is too near the lamp, the effect produced is a ring of light with a bar of light crossing it, having on either side a dark space. When the bull's-eye is too far from the lamp, an image of the flame, more or less spindle-shaped, according as the lens is farther from or nearer to its proper position, will take the place of the circle

seen when it is in focus. Any deviation from the optical axis is shown by a corresponding eccentric curvature. The proper position being reached, remove the 1-inch objective, and replace it by a half-inch, when the object is seen to occupy the centre of a brilliantly illuminated field, and if very transparent, will appear almost drowned in light. Such a condition, whilst not unfavourable for eye observation, with suitable tinted light modifiers, is by no means necessarily equally satisfactory for photography, where *contrast* is essential to the production of good results. The interposition of a coloured screen would not only lessen the light, but alter its character, and the remedy is to be found in withdrawing the condenser to a point where, whilst all detail is clearly visible, the object stands well out in relief upon the ground, or better, by using a stop of suitable size in the condenser. No negative can be considered perfect in which, upon printing, the background becomes tinged whilst the object is still insufficiently printed, and to secure the result desired, contrast must be obtained upon the screen.

For low powers the substage condenser may be dispensed with if the lamp and bull's-eye be properly managed. The bull's-eye being exactly arranged in the optical axis of the microscope, the lamp is placed in front of it (*in front* being understood to mean that the bull's-eye is between the microscope and the lamp) with the flame edge on, and a piece of thin paper being placed upon the stage, the position of the lamp is varied until a sharp image of the flame is seen upon the paper; the object being then substituted, occupying as it does the position of the conjugate foci of the bull's-eye and objective, it will be brilliantly illuminated by a cone of rays of about 30° angular extent, which will be found sufficient for any objective up to about $\frac{2}{3}$-inch focal length, unless such objective

have an unusually large angular aperture. It will be seen from the foregoing remarks how important a part the bull's-eye plays in Photo-micrography, and how necessary it is that the principles of its management should be mastered. It may not be superfluous to add that the flat side of the bull's-eye is always to be employed to receive the rays from the lamp.

Returning to the point at which, using the substage condenser and bull's-eye, the circular diatom was supposed to be in the centre of the field, and brightly illuminated, we proceed to connect the microscope with the camera by one or other of the methods described in Chap. III. The first point, having made the connection light-tight, is to centre the image upon the ground-glass screen. This, of course, must be accomplished by arranging the vertical and lateral positions of the camera suitably, taking great care that the plane of the screen is always at right angles to the optical axis of the microscope in both directions, or there will be distortion of the image, varying in amount according to the degree of angularity above or below 90° in a corresponding direction. The proper positions, once found, should be maintained, or rather made renewable at will, by means, in the case of the microscope and lamp, of blocks of wood adjusted to the position of its support, and in the case of the camera by strips either fastened to the carrier, if this be used, or to the base-board or the camera itself, so that the several parts of the apparatus may be dropped into their places without the necessity of future adjustment. By adopting this plan the writer is able to set up the whole of his apparatus within two minutes, and that with the certainty that all the adjustments are correct.

The magnification upon the screen will, of course, depend upon the distance of the screen from the

This is entirely wrong. It will vary as the distance, the exposure varies as the square of the distance.

microscope (the objective and eyepiece having been previously chosen), and will vary as the square root of the distance. As this book is intended to deal with photography and not mathematics, it need not be said that a table of square roots, such as is needful to give exact expression to the foregoing, would be out of place, and probably the method will be sufficiently exact if the square roots are worked out roughly. The magnification upon the screen is equal to that obtained by direct vision through the microscope when the screen and the object are at equal distances from the focal point of the eyepiece, which is easily determined by direct observation.

It may not be amiss, in concluding this chapter, to say that the size of image upon the screen should be such that the resulting negative may be independent of the margin of the plates, when glass plates are used. At least $\frac{3}{16}$ of an inch should be allowed all round in most cases, as plates which are of equally good quality, and equally unaffected by packing, all over, are not very frequently met with. The best plates for Photo-micrographic work are, if properly packed, those which are portions of a larger plate, so that the film is of equal thickness all over.

CHAPTER VI.

FOCUSSING.—EXPOSURE.

AFTER connecting the apparatus, and on examining the image upon the screen, it will be found that that image is indistinct, the want of sharpness varying with the distance of the screen from the eyepiece. This has to be overcome, and upon the extent to which this is done will depend, other things being equal, the sharpness of the resulting negative. For many purposes the ground-glass screen will furnish a surface sufficiently fine, but, where delicate detail has to be reproduced, the grain of even the finest ground-glass is too coarse to allow of such detail being seen, still more focussed. Other plans have, therefore, to be resorted to, and of these, by far the best are those which deal with the aerial image. Substituting, for the ground-glass screen, the transparent one ruled with fine lines, previously described, a Zeiss' aplanatic magnifier is so adjusted that the lines upon the screen are in its focus, these occupying the position which will, during exposure, be taken by the sensitive film. The image of the object, invisible to the naked eye, is brought to a focus at the same point, and, by altering the adjustment of the microscope, the image may be sharpened up to any extent, this depending only upon the optical perfection of the

magnifier. Another method, embodying the same principle, consists in using, instead of a translucent screen, a thin board pierced with holes, through which an ordinary Huyghenian eyepiece is inserted as far as the diaphragm, this being the point at which the image is formed. The writer does not think that this method is superior to the more convenient one last described.

Another method is to employ a plate which has been coated with the following solution:

Mastic, 40 grammes.	Sandarac, 160 grammes.
Ether, 4 ozs.	Benzole, 1 oz.

EXPOSURE.—With the commencement of exposure, to which all preceding preparations are but preliminary, the difficulties of Photo-micrography really begin. Up to this point the proceedings have been carried on by rule, but with the variations in colour, transparency, and so on, of the objects to be photographed, the time of exposure may vary within wide limits, and it becomes necessary to consider the relation between the colours of the spectrum most abundant in the light employed, and those which the object transmits or arrests. No absolute rules can be laid down on such a point as this. The writer has devoted much time to experiments in connection with it; but whilst the results embodied in the chapter treating of the photography of special objects will probably be found of great utility, he does not claim to have done more than indicate the lines to be followed. The remarks in the present chapter must be considered to apply entirely to white or colourless objects, such as that already mentioned in treating of illumination, and the worker is recommended to procure a slide of the diatom there spoken of. For all powers up to $\frac{1}{2}$-inch it is a most valuable test of success in Photo-micrography, and whilst not presenting any enormous difficulty by its delicacy of detail, its form and

structure are such that any error is at once perceptible, and the expense is trifling. As already mentioned, Dr. Viallanes must be credited with the first attempt to place the duration of exposure upon an exact footing; but his method implies the sacrifice of a plate at each variation of the light, if accuracy is required, and is to that extent objectionable, the delay, trouble and expense involved being considerable. It seemed to the writer that the method was susceptible of being improved, and made capable of ready application to ordinary working. Using, therefore, the standard sensitometer screen of Warnerke as a photometer he experimented with a view to determine, not the relative, but the absolute duration of exposure necessary to impress figure 14 of the sensitometer screen upon a plate of known sensibility, with a light of known intensity. The figure 14 was selected in preference to 13 (taken by Dr. Viallanes) as the standard of printing density, in order that the risk of under-exposure might be lessened. Over-exposure is, within certain limits, a comparatively venial error, but under exposure implies a weakness which can only be imperfectly made up for by subsequent intensification, and a want of detail which necessitates such "retouching" that it would be almost as little trouble to draw the object.

The results of the writer's experiments are embodied in the table which faces the title-page of this book (the position having been chosen for facility of reference) and his experience in daily working leads him to believe that the table may be relied upon to give satisfactory and sufficient exposures within the limits of development.

The only requisite for the determination is that the worker be provided with the standard sensitometer screen above referred to, with which to

determine the intensity of the light upon the ground-glass screen. Such a screen may be procured at a cost of about four shillings from Messrs. Watson, from Stanley, London Bridge Approach, or from Messrs. Baker, 244, High Holborn, and will repay its cost in a very short time in saving of plates, time, and temper.

In order to use the scale, it is advisable to fit it into a frame of wood or cardboard of the size of the inner edge of the ground-glass screen, so that no light may pass except through the sensitometer. It is furthermore advisable to use a piece of card to cover the lower numbers when the higher ones are to be read off. Everything being ready for the exposure, and especially the amount of light most suitable to the object having been determined, the object, if of any extent, is moved just out of the field and the ground-glass screen put in the camera. The last number of the sensitometer *which can be made out with certainty* when it is closely applied to the ground-glass screen, is read off, and, the sensitiveness of the plate being known, the table will at once show the needful exposure. The rule is as follows : The top line giving the last number read, from *thirty* down to twelve, and the left-hand column the "sensitometer number" of the plate, follow the line vertically from the "last number read" to the horizontal column opposite the sensitometer number of the plate used, and the exposure, in seconds, required will be that at the intersection of the two columns.

For example, it having been ascertained that the last number of the scale which can be read is 24, and the sensitometer number of the plate (as marked on the box) being 23, read down the column below 24 as far as the point where the column opposite 23 intersects it. The figure at the junction of the two is 21, and the plate in question must therefore be

exposed for 21 seconds to obtain, from a colourless object, an image of "printing density," with the light which just enables 24 to be read when the scale is applied to the back of the ground-glass screen as previously described.

Conversely, the table may be applied to finding the sensibility of an unknown batch of plates, by exposing one of them behind the sensitometer scale in the dark slide, for 27, 36, 41 or 63 seconds, the second or third of these periods being best, to a light whose intensity (shown by the last number read) is previously known. Supposing, for instance, that the light is that which enables 21 to be read, and that 63 seconds' exposure is given, if, upon development, the last number which it is possible to read in the *cleared* negative is 14, as this is the base upon which the table is constructed, it follows that the sensibility of the plate is that expressed by the number opposite the horizontal column which has its junction with that below 21 where 63 is found. The sensitometer number of the batch is therefore 22. If the number printed had been 16, the sensibility of the plate would have been two places higher, of course—that is to say, 24—or whatever the number printed above 14, so many places higher would have been the sensitometer number of the batch of plates to which the one tested belonged.

These determinations depend upon the fact that the transparency to actinic light of any square of the sensitometer scale is greater than that which immediately follows it, in the proportion of n to $n + \frac{1}{3} n$, where n is the number of seconds required to print a given number. Thus, in any given line of the table, vertical or horizontal, the numbers are always, excluding minute fractions, in the above proportions. It is evident, therefore, that it is only through the ingenuity of Mr. Warnerke that it has become possible for the writer to make this attempt

to place the difficult question of exposure upon a scientific basis. The scale is used both as a photometer and as a sensitometer; its only fault, in the writer's opinion, is that it does not go nearly far enough. The first row, and even the first two rows of figures are of no practical utility for dry-plate work, whilst an extension of the scale to 35 would provide for every possible contingency.

It has happened to the writer, and may happen to the reader who adopts the method above described, to find that the light upon the ground-glass screen allows 25 to be read easily. This, of course, renders determination uncertain, and it is necessary to obviate the difficulty by bringing the light within the limits of the scale. This, of course, might be done by interference with the optical arrangements; but such a course would be most undesirable. The best method is to be provided with a screen (which may be ground glass, but had better be prepared as will be immediately described) which brings down the power of the light a known number of places without altering the relation between the visual and actinic intensity. Taking a well-coated plate, let it be exposed for about five seconds to a gas light at a distance of 6 feet, and then developed with ferrous oxalate, fixed, *cleared*, and finished.

Now expose a plate in the way described above. (See paragraph on finding the sensibility of unknown plates.) Having exchanged this plate after exposure for another *of the same batch*, interpose the newly-made screen (or the ground glass, if preferred) between the bull's-eye and the substage condenser. Expose now the second plate for the same time as the first to the light thus modified, and develope both together, so that no difference of treatment may affect the result. If the number printed upon the first be 15, and upon the other 8,

or whatever may be the difference between the last numbers perceptible, this of course represents the amount by which the actinic power of the light has been lowered by the interposition of the screen. This screen may very appropriately be named the reducer, and the reducing effect, in places of the sensitomer, should be marked upon its surface. Now to use it. Supposing that its reducing power is 7, and that the light upon the screen allows 25 to be read without it. Upon interposing it, if the light be reduced to 21, it is clear that the light available without would be 28, and the column beneath this last number in the "last number read" line will give the necessary exposure according to the sensibility of the plate about to be inserted. Of course the reducer is not to be employed during the actual exposure. Contrast is a question of angular aperture more than of amount of light, and since the *relative* amount of light upon field and object would be but slightly affected by any reduction by interposition, the effect would practically be simply to lengthen the exposure without improving the negative. Should it happen that the light available is less than 12, the table can still be made use of. Thus, according to the table, a plate which gives 25, requires, with a light of 12, one exposure of 426 seconds. Now, if the light be only 11, the number *vertically below* 426 will give the exposure required—viz., 568 seconds—and the same applies to still lower degrees of light, since the *vertical numbers increase in exactly the same proportion as the horizontal ones.*

When magnesium is employed as the source of light, the scale is practically useless, as the actinic quality is so different from that of the Paragon or any other burner. Its intensity, moreover, varies so much according to the manner in which it is burnt with relation to the condensers, and whether

one or both are employed, that it is useless to attempt to give Photo-micrographic data. Experiments with naked light, however, show that the actinic intensity of magnesium light is 20 places higher on the scale than that obtained from the Paragon flame when used on edge, at the same distance, for the same time, the flame being turned up to the highest point compatible with the absence of smoking.

CHAPTER VII.

METHODS OF DEALING WITH SPECIAL OBJECTS.

In one sense all objects may be considered special, since no two give exactly the same result when similarly treated, and even two apparently identical slides will often fail to do so.

There are, however, certain variations which require special consideration, and these may conveniently be classed thus :

Objects seen by dark-field illumination.
Objects whose surface is not flat.
Coloured objects.

These three classes will be found to include most of those which entail a departure from the ordinary routine. The treatment of minute detail, such as that found in some diatoms, and the photography of bacteria, demand little more than that special attention be paid to the proper illumination of the object, and that the light be cast upon the object in as narrow a cone as will allow the needful detail to be made out distinctly for focussing, whilst when using very high powers, Dr. Maddox's caution, to allow time for alterations of temperature before the final focus is settled, is by no means superfluous.

Of the photography of objects belonging to the first class mentioned above, it is in the writer's experience, it may be said at once, the easiest of all Photo-micrographic work. Given a suitable power, dark field

See Jennings. Phot p. 21

and a proper light, the light available can be so exactly estimated, proceeding as it does from the object itself by direct reflection that possible errors of exposure are reduced to a minimum.

The estimation of the light, however, cannot of course be carried out in the way previously described, inasmuch as the field is dark. The sensitometer scale is, therefore, applied directly over the image of the object upon the ground-glass screen, and, as before, the last number which can be thus read determines the exposure. Proceeding in the above way, the writer has secured some most beautiful photographs of foraminifera, the field of the negative being "clear glass," and the images standing sharply out upon it. When printed upon Permanent Bromide Paper, these negatives yielded prints hardly to be excelled by the most exquisite drawings. The dark field was produced by stopping out the central rays of the hemispherical substage condenser previously described. By this means a field of a beautiful velvet black, upon which the objects shone out like pearls, was obtained with Zeiss' A objective and a B eyepiece. When the object is mounted upon a black background the difficulties are much greater, unless a very powerful source of light be used, for the object has, of course, to be focussed, and this, *experto crede*, is by no means easy. The best way is to arrange the light so that the rays make as small an angle as possible with the axis of the microscope; but in any case the exposure is likely to be prolonged.

Objects which have other than plane surfaces are less easily dealt with, and their satisfactory reproduction is a matter entailing considerable trouble. For low powers *Aulacodiscus margaritaceus* is an excellent object upon which to practise this branch of Photo-micrography. Each of the large pentagonal areolæ has within it a delicate membrane

with a circular opening, and to reproduce the appearance of these areolæ, from centre to margin, and to get the margin sharp, as well as the processes just within it, will tax the beginner's powers to the uttermost. When he has, however, mastered the diatom in question, he will be entitled to consider himself pretty well qualified to deal with any object of the same class that he may meet with.

Presuming that the fine adjustment has the milled head divided, as it should have, the next point is, will it register correctly?—that is to say, with a half-inch objective, and an image $2\frac{3}{4}$ inches in diameter upon the screen, if the index point to zero when the *umbilicus* of the diatom is in focus, and to 4 when the margin is at its sharpest point, will the index stand at zero again when the *umbilicus* is again focussed? If so, the best method of dealing with such objects is open to the worker, but the chances are that he will find only one fine adjustment in a dozen or more, which will satisfy these conditions. The method consists in noting down the several points beyond zero at which the planes, necessary to be photographed in order to produce a complete image, come successively into focus. The fine adjustment head is then returned to the zero point, the plate inserted, and a proportional fraction of the exposure (increased, however, by one-third) is given at each point noted down. In this way, under favourable conditions, and with not more than three or four alterations of focus, the resulting negative gives no clue to the manner in which it was obtained, provided the fine adjustment have registered correctly, and be free from lateral movement.

If error of the fine adjustment be present, but small in amount, the focussing may be done, though less satisfactorily than by the foregoing method, by rotating the milled head through a distance slightly

exceeding, on either side, that found to represent the distance between the extreme planes to be photographed. This method answers fairly well for short exposures, but of course the longer the exposure, the more wearisome does it become, and the risk of blurring the image from movement is increased considerably; in fact, the method altogether is only to be recommended as a *pis aller*.

Another mode, recommended by several authorities, consists in stopping down the objective, or the substage condenser, and so increasing the depth of focus; but this can rarely be done without a commensurate sacrifice of definition. Using a lower power, and increasing the power by the use of a higher eyepiece or a longer camera, is open to a similar objection, though conversely, inasmuch as the result is practically to increase the angle of the objective, and certainly to diminish its working distance. It may be taken as a safe working rule that no objective will bear greater magnification, upon the screen, than twice that which is its best for direct observation in the ordinary way. Beyond this point there is sure to be a falling off in penetration. With a flat object greater latitude may be allowed.

On the whole, the writer is inclined to think that no method of altering the adjustment during exposure is likely to prove entirely satisfactory in which the movement of the body of the microscope, or at all events that of the lens-setting, is not directly registered upon an enlarged scale. A very simple method of doing this may be found in the reflection of a beam of light from a suitably arranged mirror, and such an arrangement the writer hopes shortly to work out and publish. The delicacy to be obtained by this plan, and the simplicity of the necessary mechanical arrangements highly recommend it. The length of the

scale is limited only by the dimensions of the room in which the apparatus is being worked, and it may easily be adapted to the most delicate micrometric measurements, whilst the resistance involved is so small that it will not interfere with the accuracy of adjustment of even the highest powers.

Whichever of the methods of obtaining pictures of unlevel objects may be selected, it is needful (and indeed in any case it is absolutely necessary) to know whether the objectives employed have their visual and actinic foci coincident. This may be tested in the following manner: Using the diatom already mentioned, focus the portion midway between the centre and the margin upon the screen, and expose a plate. If the developed plate shows a clear image of the part focussed, the objective may be considered satisfactory. If, however, the margin be reproduced most sharply, it is evident that the actinic focus is above the visual, and a trial must then be made to determine the exact amount of correction required, in one direction or the other, as the result of the first trial may show. The correction once made should be registered for reference; in fact it is best to mark it upon the objective.

In dealing with coloured objects, the difficulties met with come under quite another category than those already dealt with in the last and preceding classes. The relative *actinic* transparency of the different coloured objects met with is so different, and the relation between that and the *visual* transparency so variable, that the ordinary methods are not available in dealing with them. Two courses are open to the worker; either he may employ ordinary plates and coloured screens, interposing the latter between the lamp and the object, or he may avail himself of the "orthochromatic" plates which have of late been brought so prominently forward. The

truer description of these plates would probably be "isochromatic," for their effect is to increase the power of the film to respond to the less refrangible rays of the spectrum, green, yellow, and orange, and to some extent, red; though in this last particular the writer has not yet met with any which answered his expectations. They are isochromatic, and not truly orthochromatic, because all the rays of the spectrum are, as far as may be (except the red), equally active upon the film, so that whilst there is an unquestionable gain, yet the effect of colour upon the retina is by no means reproduced in the photograph. The writer has subjected the orthochromatic plates prepared by Messrs. Dixon to the severest test possible, in applying them to the photography of objects viewed under polarized light; and in saying that, except in the red, there appeared to be little difference in the effect, upon the film, of the different tints, which were purposely so selected as to present the greatest possible difficulty, the writer believes that he can give no higher testimony to their excellence. Unfortunately, however, for Messrs. Dixon, their process proved to be an infringement of the patent rights of Messrs. Edwards, and the plates in question are no longer available. The last-mentioned firm, however, having courteously placed a supply of their "Isochromatic" plates at the writer's disposal, he has tested them similarly, and with an equally satisfactory result. For objects which present but shades of a single colour, sections stained with hæmatoxylin, for example, the method of interposing coloured screens, in combination with the use of ordinary plates, seems preferable, from the writer's experiments, and this will now be described.

The rule for the selection of the particular screen to be chosen in the case of any given colour is a

simple one : Use the tint which most nearly reduces to a neutral grey the colour of the object when the latter is viewed through it. The reason is also simple : A colour which gives good contrast upon the screen may be entirely devoid of actinic contrast. A violet or a blue section stands out sharply enough when seen through the microscope, but inasmuch as the colours which it transmits are also the most active in the luminous background upon which it is seen, actinic contrast is absent, though visual contrast may be all that could be desired.

The screens experimented with by the writer were obtained from Mr. Tait, of Holborn, who will furnish similar colours when desired.

Romyn [illegible] [illegible] [illegible] A.H.

For brown preparations, such as insects, blue is the best colour to interpose; for violet, signal-green ; but it is not possible to do more than indicate the general rule which has been formulated above—viz., to use such a coloured screen as reduces the colour of the object to a neutral tint.

The use of coloured glass necessarily lengthens the exposure considerably. The experiments of the writer gave the following results :

Taking the visual intensity (represented by the last number which could be read upon the screen) and the actinic intensity (represented by the last number impressed upon a plate exposed for a given time) as 25 with the naked flame of the Paragon lamp, the effects of using glass of different colours were tested in both ways, as shown in the table.

Colour.	Actinic Intensity.		Visual Intensity.
Blue	19 (6)	......	15
Signal-green ...	18 (7)	......	19
Yellow, No. 2...	17 (8)	......	23
" No. 3...	15 (10)	......	22
Green	13 (12)	......	19
Violet (Puce) ...	12 (13)	......	12
Yellow, No. 4...	8 (17)	......	20

It will be seen that the relation between the visual and actinic intensities is by no means the same in every case ; but as this has no bearing further than that the direct use of the sensitometer screen is of no avail, the point need not be here considered. It should be added that all arrangements as to illumination, contrast, and so on, should be made before the screen is interposed between the bull's-eye and the substage condenser.

The use of the table just given hardly requires explanation. Whatever the intensity of the light upon the ground glass when the light is not modified, the effect of the coloured screens will be to diminish the photographic power by the number of places denoted by the figures in brackets. Thus if the bare light available is enough to enable 23 to be read, the exposure required when blue is used will be as if 17 only had been visible, and so on. Should the worker be unable to obtain glass of the particular shade used by the writer, he can make another table for himself with very little trouble, using plates of known sensibility, a light of known intensity, and the same exposure for every colour.

Where objects are of very widely different degrees of transparency in different parts—*e.g.*, the wings and the body of a fly—hardly any method of exposure will give perfect results. In such cases, the best plan is to use blue glass in taking the negative, which should be on paper, and the back of the negative can then be worked on to any required extent with lead pencil or gamboge.

It may be useful to note that good sections stained with picro-carmine give excellent results, without the use of any coloured screen; but the sections *must* be thin, otherwise it will be necessary to interpose the signal-green glass.

The topic of instantaneous Photo-micrography demands a few words. The only difficulty is the

illumination, but whilst the writer, using magnesium ribbon and low powers, has succeeded fairly well, much remains to be done before the processes can be considered to have passed the experimental stage. Some of the writer's results will be found in the journal of the Linnean Society (*Zoology*, April, 1887), in illustration of a paper on "The Natural History of the Deros," plates III., IV., and V.

CHAPTER VIII.

DEVELOPMENT.

THE processes connected with the treatment of the plate after exposure call for careful study, as they influence largely the character of the finished prints, and moreover offer the best, and for many purposes the last, opportunity of correcting previous errors of exposure and illumination.

The two developers mentioned in Chap. V. are both well suited for Photo-micrographic use, and in point of cost there is but little to choose between them. The pyrogallic developer has the advantage in working of greater flexibility, and in this respect is better suited for use in cases of doubtful exposure. The ferrous oxalate has the advantage that negatives known to be correctly exposed may be safely left in it for four or five minutes with little or no movement, that they are easily freed from stain, that they have a beautiful blue-black tint, and print rapidly. The pyrogallic solution can only be used for two negatives at most, and that only when they are developed in quick succession, whilst the ferrous oxalate, if poured into a bottle after use, can be employed for many negatives, and can be recuperated, when its action becomes torpid, by the addition of a small quantity of hyposulphite of soda.*

* It may be well to add here that the bottle into which it is poured should be no larger than will hold the quantity in use, and should preferably have a glass or caoutchouc stopper.

The latter, however, is certainly less under control than the pyrogallic developer. With these indications a little experience will enable the worker to decide for himself which is best to use in any given case.

The golden maxim in development is, "Never be in a hurry;" and beaiing this in mind, we proceed to indicate the method to be adopted in developing a plate with ferrous oxalate solution. Two drams of iron solution having been measured, make the quantity up to eleven drams with the oxalate of potash solution. Take a dish of suitable size, place the plate in it by a feeble light, face (*i.e.*, film) upwards, and pour the solution gently over the surface. A slow rocking motion is now given to the dish, in order to flood all parts of the plate equally, and to avoid air-bubbles (which would leave clear spots after fixing), and the effect of the developer is watched. Owing to the non-actinic colour of the developer, more light is allowable than if pyrogallic acid were being used. If the image begins to come up within half a minute, let the action continue until all the required detail is visible, then pour a dram of iron solution into the measure, add the developer to it, and pour over the plate again. This will give density, and if all go well, the development should be continued until the image is perceptible in its coarser outlines upon the back of the plate.

Suppose, however, there is no sign of the image after half a minute, wait until at least two minutes have elapsed, and then, if there be still no sign, pour a dram of iron solution into the measure, add the developer to it, and try again. If there be still no effect, add cautiously a few drops (three to five at a time) of a weak solution of hyposulphite of soda, made by diluting a little of the fixing solution with twenty times its bulk of water. Is this fails no

good result is likely to be got, and the plate may as well be washed off, or if preferred, it may be well washed, and re-exposed, though a very much longer exposure is necessary for the plate thus treated—at least twice or three times the normal. In adding hyposulphite solution, whether to increase the action of a normal developer, or to revivify an old one, the addition must be made very carefully, and the effect of each drop watched, or a film of metallic silver will be deposited, and this can never be entirely got rid of, the printing qualities of the negative being injured to a corresponding extent.

Should the image appear immediately the developer is poured on to the plate, return the solution to the measure at once, and rinse the plate, then add three to five drops of the solution C (the restrainer for both developers) and begin again. In an extreme case it is well to flood the plate with solution C without stopping to wash it, merely first pouring off the developer as quickly as possible. The remaining steps are, much as before, stated for a normal exposure, and we repeat that it is for such exposures that iron development is best adapted.

The main principles in developing with pyrogallic acid are identical with those to be considered in using ferrous oxalate.

The solution, made up of A, B, and C, in the proportions stated in Chap. V., is poured over the plate, and the effect watched as before. If the image appears too quickly, add more of solution C, if too slowly, more B, if naturally, when the detail is all out, add an additional dram of B, to secure density, remembering, whatever developer be used, that it is always easier to intensify satisfactorily a thin negative, than to reduce an over-dense one, and that development should never be continued until *all* detail is visible upon the back. In using the pyrogallic acid developer, the dish must be kept

in constant motion, and when making additions to any developer, the fresh re-agent should be placed in the measure, and the developer added to it from the dish, otherwise streaks will result from unequal action.

Should greater density be required, the proportions of A and B in the developer may be increased.

The development having been carried sufficiently far, the solution is poured off, the plate rinsed several times—six or eight at least—with clean water (held under the tap, if there be one in the dark room), and when thoroughly washed, removed to the dish containing the fixing solution. In this it is to remain until at least five minutes after it has become transparent all over. Prolonged immersion will do no harm, but insufficiently fixed negatives will turn yellow, all over or in patches, and become almost unprintable.

After removal from the fixing solution, the plate is again washed, and placed in the clearing solution for two minutes, in order to remove any stain caused by the developer, after which it may be examined in the light to see if there is any stain left, and if so, it must be at once returned to the clearing solution for as long as may be necessary.

A final washing of several hours in running water will complete the process, and the negative should then be very carefully brushed over under the tap, with a soft camel-hair brush, avoiding scratching of the film, after which it must be dried standing on edge in order that no dust may fall upon the adhesive film. The drying process may be much accelerated by flooding the plate with methylated spirit, allowing the spirit to remain on for two or three minutes, and then pouring it off and repeating the process. Heat must not be used, or the film will melt.

Where rapidity of production of prints is of more importance than permanence of the negative the final washing may be much shortened; in fact it is possible to conclude the whole process, from the exposure to the finished print, in half an hour, but the keeping qualities of both negative and print will be much deteriorated.

A few cautions may not be out of place. Avoid any impurity in the dishes used ; pyrogallic acid and ferrous oxalate are bad for each other, and separate dishes should be kept for them. Hyposulphite of soda, too, is an undesirable contamination, except as above stated. Air-bubbles which are not removed by rocking should be got rid of with a camel-hair pencil, *one being kept for each developer*, Plates should not be allowed to lie in any solution without occasional rocking, or there will be great risk of crape-like markings on the film which no subsequent treatment will remove.

Frilling and blisters are caused by separation of the film from the plate, owing to the osmotic action set up through the gelatine. The former, if small in extent, may be remedied by the alum bath after fixing; the latter are best dealt with by a careful use of methylated spirit applied to them after the final washing. This contracts the film, and so with care blisters, even of large extent, may be remedied. If they should give much trouble, it is best to alter the brand of plates in use. Fog, or veiling of the image, result from access of actinic light to the plate before or during development. The camera and the dark room light should each be looked to.

Over-density, providing the worker has adhered strictly to the exposure table, is most likely to be due to over-development. The effects may to a great extent be overcome by the immersion of the plate, after fixing and thorough washing, in a solution of hyposulphite of soda, to which is added, drop by drop,

a saturated solution of *red* prussiate of potash. If the iron developer have been used, the washing must be very thorough, or prussian blue will be formed. If the plate have been cleaned and dried, it is necessary to dip it in a weak solution of hyposulphite of soda before applying the reducer, the action of which must be very carefully watched, as it is apt to become uncontrollable if allowed to go too far. Reduction is, however, at best an unsatisfactory process, and it is much easier to intensify a thin negative, or even to print from an unintensified one, with good results, than to reduce an over-dense one.

Intensification, where necessary, is easily effected by immersing the plate, after well washing, in a saturated solution of bichloride of mercury (corrosive sublimate, which is excessively poisonous), until it is as white as it will become, then washing for half an hour in running water, and flooding with a solution of ammonia (five drops of strong ammonia, 880°, in each ounce of water), until thoroughly blackened, and again washing. If too much density have been thus given, it may be reduced, or entirely removed, by immersion in weak hyposulphite of soda solution, until the desired point is reached.

The finished negative may be varnished with any of the preparations sold for the purpose. The writer, however, has never adopted this plan, and is inclined to think that negatives containing fine detail print best when not varnished.

CHAPTER IX.

PRINTING.

THE final test of the success of all the previous processes is now to be applied, and the last opportunity for correcting previous errors also presents itself. Remembering that the great test of a satisfactory negative, other things being equal, is that the print should have a white background, whilst the object is shown upon it with sufficient strength, it remains to be seen what are the steps necessary to be taken to this end.

For many purposes the old-fashioned silver prints still remain unsurpassed, and the convenience of being able to control all the steps of the process by actual inspection, is a great advantage in some cases. This method will therefore be described first, the alternative plan of employing paper coated with an emulsion similar to that of which the negative film is composed being reserved for treatment at a later stage.

Assuming, then, that a print is to be made upon the old-fashioned albumenized paper, it is advisable to purchase the paper of a good maker, ready sensitized, and in quantities not larger than will afford three months' supply at most. The fresher the sensitized paper the better will be the results. The negative having been thoroughly cleaned upon

the glass side is laid in a printing frame, face upwards, and the sensitized paper, a little larger than the required print, is placed with its glossy surface in contact with the film, the back of the printing frame is then laid upon the paper, and the frame closed, and turned up to the light. The best light for printing is that obtained by reflection from white clouds on a sunny day. Direct sunlight is, as a rule, to be avoided, though it may answer well with very dense negatives, or those which have a deep yellow stain.

If the negative be thin, and it is desired to print from it without intensifying, varnishing the back of the negative with yellow varnish, or interposing a piece of yellow glass between it and the light, must be had recourse to, and by this means an otherwise unprintable negative may be made to yield satisfactory results. A hard, chalky negative, with high lights and dark shadows, may be much improved by printing in a light which has filtered through a blue shade. When one part of a negative is more dense than another, recourse must be had to retouching, or stopping out of light during printing. Mr. Jennings advocates the use of cotton wool over the more transparent parts when they are sufficiently printed ; but this may be a great nuisance, and a better plan, in the writer's opinion, is, when an object is likely to yield such a negative, to take it on negative paper, which can be worked over upon the back with pencil, or Indian ink, or a yellow stain, such as one of the aniline dyes, to any required extent. Such negatives, if rendered transparent by one of the methods recommended by the manufacturers of the tissue, print almost as quickly as glass ones.

As soon as the print in the frame has reached a sufficient point of distinctness (which should be somewhat in excess of that desired in the finished

print), it is removed from the frame, and when a sufficient number have been done, they are next to be submitted to the toning process.

The first step in toning is to wash out of the prints all the unchanged silver salt, which is done by washing in two or more waters until all trace of milkiness has disappeared. This, and the subsequent processes, may be carried on in weak daylight, in order that the colour may be satisfactorily judged. After washing, the toning bath is brought into requisition, and in it the prints, trimmed to the desired size, are immersed, a few at a time, and allowed to remain, with constant motion, until they are of the desired colour. They will be slightly darker when dry, so that this must be allowed for.

The toning bath is composed of

Chloride of Gold, 4 grains,
Acetate of Soda, 109 grains,
Distilled Water, 1 pint,

and must be made the day before using.

After toning follows another washing, and the prints are then transferred to the fixing bath, in which they are to remain from ten minutes to a quarter of an hour, with free exposure to the action of the solution. Prints which are allowed to stick together will be, very probably, insufficiently fixed.

The fixing solution should be about two-thirds the strength of that used in negative work.

From the fixing solution the prints are returned to the washing tray, and after half an hour's washing in running water, are ready for the final process. The finished prints are placed face downwards, one above another, on clean blotting paper, the superfluous water squeezed out, and thin, *fresh*, starch paste is brushed over the back of the upper one, which being then transferred to its card mount, the next one is left ready for treatment in like manner, and so on.

After mounting, it is a good plan to roll the print with a smooth, hard ruler, which will press out the superfluous starch and give a certain amount of gloss to the surface of the print.

It will be obvious that the foregoing method of working is only applicable by daylight, the most sensitive albumenized paper being but little, or not at all, affected by exposure to artificial light. For those whose Photo-micrographic work must all be done by lamplight, therefore, the more sensitive positive papers, of which there are several in the market, offer great advantages. Of these, perhaps the best is the "permanent bromide paper" of Eastman; but there are several others almost as good. The tones produced by most of them are entirely unlike those of a silver print, being confined to shades of black and white; in fact, when well executed, the prints thus obtained most nearly resemble a good mezzotint engraving, and perhaps convey a more faithful idea of the object than an ordinary one on albumenized paper. With dark-ground illuminated objects, no other method is entirely satisfactory, and negatives of them should certainly be printed by this or by the platinotype process. The latter yields the most permanent prints of any, inasmuch as the image is composed of metallic platinum, deposited in the pores of the paper, and is more enduring than the paper itself. It is not necessary to enter into details as to the working of these positive papers ; they are exposed beneath the negative in the ordinary way, developed with ferrous oxalate, and fixed and cleared like an ordinary *negative*. It is advisable to use a standard source of light, say a paraffin lamp-flame, which enables 24 of the sensitometer screen to be read at a given distance. The negatives being then held always at a particular distance from the screen during printing, the results of a few experiments

will enable the worker to determine very nearly the proper amount of exposure to be given for any given negative according to its density; and if the density also be tested by the screen, he will be able to construct tables—one for negatives developed with ferrous oxalate, the other for those developed with pyrogallic acid—which will reduce his results almost to a certainty.

The platinotype process differs in its working details from the emulsion processes, and is only allowed to be worked under licence from a company, who have also a monopoly of the materials. The developer is a hot saturated solution of oxalate of potash, and as the character of the prints depends largely upon the temperature of the bath, and as, moreover, the materials, or some of them, require extreme care, especially in the matter of protection from damp, the process is not so well adapted to the wants of the amateur as the more easily managed ones connected with the working of the bromide positive papers. In the platinotype process, a feeble image is produced upon the paper during exposure, whilst the image upon the bromide paper is entirely latent until developed. The latter, therefore, is entirely dependent for success upon the result of experiment as to the particular printing qualities of any given negative. But the right exposure once determined, any number of prints of exactly the same strength can be obtained, and when carefully managed, the results are almost indistinguishable from those obtained by the platinotype process, whilst, if wished, a high polish may be given to the surface of the prints by drying them upon a plate of vulcanite, taking care that no air-bubbles are present. The best way of securing this is to float the prints on to the vulcanite in a large basin of water.

The choice of any of the above methods for a given case is largely a matter of taste. There is,

perhaps, more certainty about the result of albumenized prints, inasmuch as the first stage, which is after all the essential one, is entirely under control; but the writer is bound to confess that he himself seldom uses it except to produce an image giving rapidly an idea of the success of the negative, and that Eastman's bromide paper is his sheet-anchor for permanent prints. In the matter of expense, there is little to choose between the two last-named processes, since the cost of the toning bath is sufficient to make up for the difference in the price of the media on which the prints are produced.

CHAPTER X.

APOCHROMATIC LENSES.

CONCLUDING REMARKS.

ONE of the great difficulties in the way of obtaining perfect Micro-photographs has hitherto been the impossibility of absolutely correcting the objectives employed so as to get rid altogether of the coloured fringes produced by the secondary spectrum. For low powers, or short distances from screen to object, the difficulty was not so greatly felt; but with the higher powers it was very sensible, and even in lenses of the best class could not be said to have been entirely abolished. For several years past, however, attempts have been made, under subvention from the Prussian Government, by Messrs. Abbe, Schott, and Zeiss, to discover a glass which would enable them to manufacture objectives which were free from the objection above mentioned, and with such success have they executed the difficult task before them, that within the last few months objectives have been placed upon the market which, under the severest tests, have shown a freedom from colour surpassing anything hitherto accomplished.

The method adopted is hardly suitable for discussion here; but having had the opportunity of

testing the lenses in question somewhat severely as to their photographic qualities, the writer has been much pleased with the results. The lower powers do not appear (and this is what he expected) to be superior to carefully-made English lenses; but with the higher powers experiments made with magnifications upon the screen of from 1200 to 3000 diameters, showed that the advantages of the new lenses were very great. Part of this advantage is no doubt due to the fact that the eyepiece employed has received special attention. In lieu of the ordinary eyepiece, which may or may not be used, at the will of the photographer, it is absolutely necessary to employ with the apochromatic lenses what is called the "projection" eyepiece, which is itself so constructed as to throw an image free from colour upon the screen. How much of Prof. Abbe's success is due to the care bestowed upon the eyepiece it is impossible to say, as the two—eyepiece and objective—*must* be used together; but there is no doubt that, thus using them, they accomplish all that is claimed for them, or very nearly. The working distance of the higher powers, though longer than that of ordinary objectives of the same power, is unfortunately very short, so that the cover glasses must be very thin; but other things being equal, the apochromatic combination will probably give a great advantage to those who wish to photograph the minuter forms of life. The objectives in question are manufactured by Zeiss, and Messrs. Baker are the London agents. The prices are very high, and from the exceedingly complicated construction, are not likely to become much lower. But Zeiss having shown the way, and the glass being obtainable by any manufacturer, it will probably not be long before the English opticians will avail themselves of the opportunities offered them for maintaining their supremacy; in

fact, Mr. Powell has already produced a glass but little inferior to those of the German firm, for direct observations, though not so well adapted for photographic purposes.

CONCLUDING REMARKS.

Having in the foregoing pages dealt at length with the salient points of scientific Photo-micrography, it may be of use to the tyro to recapitulate the chief ones to which he ought to give attention in order to ensure success, or at least, as far as may be, avoid failure.

There is certainly no royal road to photography; but brains come in usefully at every stage, and failure, fairly considered, and tracked to its source, contains within itself the promise of success.

If the writer were asked, "What is the best motto for a Photo-micrographer?" he would unhesitatingly reply "Festina lente." Don't hurry in arranging the object, in adjusting the lamp, in centreing the bull's-eye, in estimating the light, in making the exposure, in developing the negative, in fixing or washing it. It is infinitely better to ensure a successful first trial than to have to make a second to amend faults caused by haste, and it certainly takes less time. Haste in estimating light will certainly result in under-exposure, and it is better to give twice than half the proper amount. Detail not photographed can never be got out by any amount of development or intensification ; and hurry in development is very apt to result in a flat negative, utterly wanting in vigour and contrast, yielding feeble and unsatisfactory prints.

Be very careful as to the light to which the plates are exposed, or the results will be disastrous, especially with the more rapid plates. Don't think that

"it will do." Try it, by leaving a plate exposed for at least a quarter of an hour, in the dark room, to the light used for developing, and if ten minutes' immersion in the iron developer gives no black stain to the surface, then it *will* do. It is better to waste one plate than a dozen.

Begin with low powers and easy objects. The processes are less difficult, the light is more readily arranged, and the exposures are shorter. Failures at first are apt to discourage, and it is well, therefore, to make sure of some degree of success at the start. Don't imagine that you can estimate the light satisfactorily by reading the sensitometer screen directly after the eyes have been exposed to a bright light; give them a minute's rest in darkness, and then take the last number you are *sure* of.

It is unfortunate that the numbers upon the screen run consecutively; but the misleading tendency can be overcome by an effort of the will, and this effort must be made if the table is to be employed with success.

Take every opportunity of examining the productions of more experienced workers. Try to imitate them, and before long that which seemed to be difficult will become easy, and you will be encouraged to yet higher flights, and will confess that in Photo-micrography, as in every other pursuit,

"LABOR OMNIA VINCIT."

R. O. HEARSON,
PRINTER AND STATIONER,
LEADENHALL HOUSE,
LONDON, E.C.